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Nobuaki ABETitle: IMAGE COMPRESSION AND EXPANSION  
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ADDRESS TO:

Assistant Commissioner for Patents  
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Washington, DC 20231

## APPLICATION ELEMENTS

## ACCOMPANYING APPLICATION PARTS

1. ☒ Fee Transmittal Form
2. ☒ Specification [Total Pages 27]  
(preferred arrangement set forth below)
  - Descriptive title of the Invention
  - Cross References to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to Microfiche Appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
3. ☒ Drawing(s) (35 USC 113) [Total Sheets 9]
- ☒ Oath or Declaration [Total Pages 3]
  - a. ☒ Newly executed (original or copy) ☐ Unexecuted
  - b. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 18 completed)  
[Note Box 5 below]
    - i. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s)  
named in the prior application, see 37 CFR 1.63(d)(2)  
and 1.33(b).
- ☐ Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy  
of the oath or declaration is supplied under Box 4b, is considered  
as being part of the disclosure of the accompanying application  
and is hereby incorporated by reference therein.
- ☐ Microfiche Computer Program (Appendix)
- Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)
  - a. ☐ Computer Readable Copy
  - b. ☐ Paper Copy (identical to computer copy)
  - c. ☐ Statement verifying identity of above copies

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☒ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
14. ☐ Small Entity Statement(s) ☐ Statement filed in prior application,  
Status still proper and desired
15. ☐ The prior application is assigned of record to \_\_\_\_\_
16. ☒ Foreign priority claimed
  - a. ☒ Claim of Priority
  - b. ☒ Certified Copy of Priority Document(s)
17. ☐ Other: \_\_\_\_\_  
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18. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior Application No. \_\_\_\_\_/\_\_\_\_\_, filed \_\_\_\_\_.19. ☐ Amend the specification by inserting before the first line the sentence:

This application is a \_\_\_ continuation-in-part, \_\_\_ continuation, \_\_\_ division, of Application No. \_\_\_\_\_/\_\_\_\_\_, filed \_\_\_\_\_.

Address all future correspondence to Customer No. 7055 at the present address of:

GREENBLUM & BERNSTEIN, P.L.C.  
1941 Roland Clarke Place  
Reston, VA 20191  
(703) 716-1191

Date


 Signature  
 Reg. No. 33,329
Bruce H. Bernstein, Reg. No. 29,027  
Typed or Printed Name

P18580.A02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Nobuaki ABE

Appl. No : Not Yet Assigned

Filed : Concurrently Herewith

For : IMAGE COMPRESSION AND EXPANSION APPARATUS  
AND PIXEL NUMBER INCREASING APPARATUS

**PRELIMINARY AMENDMENT**

Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

Prior to calculation of the filing fees and the examination of the above-identified patent application on the merits, the Examiner is respectfully requested to amend the claims as follows:

IN THE CLAIMS

Please amend the claims as follows:

Claim 3, line 2, change "one of the claims 1 and 2" to --claim 1--.

Claim 5, line 2, change "one of the claims 1 and 2" to --claim 1--.

Claim 6, line 2, change "one of the claims 1 and 2" to --claim 1--.

Claim 7, line 2, change "one of the claims 1 and 2" to --claim 1--.

Claim 8, line 2, change "one of the claims 1 and 2" to --claim 1--.

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Claim 9 line 2, change "one of the claims 1 and 2" to --claim 1--.

REMARKS

By the above amendment, claims 3 and 5-9 have been amended to delete multiple dependency.

If there should be any questions, the Examiner is invited to contact the undersigned at the telephone number listed below.

Respectfully submitted,  
Nobuaki ABE

  
Bruce H. Bernstein  
Reg. No. 29,027

*Reg No*  
*33,329*

January 21, 2000  
GREENBLUM & BERNSTEIN, P.L.C.  
1941 Roland Clarke Place  
Reston, VA 20191  
(703) 716-1191

# IMAGE COMPRESSION AND EXPANSION APPARATUS AND PIXEL NUMBER INCREASING APPARATUS

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to an image compression and expansion apparatus for recording image data obtained by reducing the number of pixels of an original still image on to a recording medium and later reading the image data from the recording medium and restoring the original image.

### 2. Description of the Related Art

In the past, as an example of image compression processing in an image compression and expansion apparatus, it has been known to find an average value of a predetermined number of pixel values included in the large number of pixels forming an original image, to generate a single pixel and to record a reduced image comprised of such pixels on to a recording medium. Further, in the image expansion processing in the image compression and expansion apparatus, the reduced image read from the recording medium is subject to interpolation so as to generate an enlarged image of the same number of pixels as the original image.

On the other hand, another image compression and expansion apparatus is known to record DCT coefficients obtained by application of a two dimensional discrete cosine

transformation to a reduced image on to a recording medium and apply a two dimensional inverse discrete cosine transformation to the DCT coefficients read from the recording medium to obtain IDCT coefficients. The IDCT coefficients correspond to part of the pixels contained in the pixels of the original image. By applying interpolation to the IDCT coefficients, it is possible to generate an enlarged image of the same number of pixels as the original image.

The enlarged image reproduced by an image compression and expansion apparatus should ideally match the original image, but since part of the information included in the original image is lost at the time of generating the reduced image, normally the original image is not matched and the quality of the image becomes relatively poor.

#### SUMMARY OF THE INVENTION

An object of the present invention is to provide an image compression and expansion apparatus for reproducing an expanded image corresponding to an original image from a reduced image, which can improve the quality of the expanded image.

According to a first aspect of the present invention, there is provided an image compression and expansion apparatus comprising a reduced image generating processor, a reduced image recording processor, an orthogonal transforming processor and an expanded image generating processor.

The reduced image generating processor generates, based on original image data arranged in a first matrix comprised of a plurality of pixels, reduced image data arranged in a second matrix comprised of a smaller number of pixels than the first matrix. The reduced image recording processor records the reduced image data in a recording medium. The orthogonal transforming processor reads the reduced image data from the recording medium and applies orthogonal transformation to obtain orthogonal transformation coefficients arranged in the second matrix. The expanded image generating processor applies inverse orthogonal transformation to the orthogonal transformation coefficients to obtain expanded image data arranged in a third matrix comprised of a greater number of pixels than the second matrix.

According to a second aspect of the present invention, there is provided an image compression and expansion apparatus comprising a reduced image generating processor, a reduced orthogonal transformation coefficient data recording processor and an expanded image generating processor.

The reduced image generating processor generates, based on original image data arranged in a first matrix comprised of a plurality of pixels, reduced image data arranged in a second matrix comprised of a smaller number of pixels than the first matrix. The reduced image recording processor records reduced orthogonal transformation coefficient data obtained by

orthogonal transformation of the reduced image data, in a recording medium. The expanded image generating processor reads the reduced orthogonal transformation coefficient data from the recording medium and applies inverse orthogonal transformation to obtain expanded image data arranged in a third matrix comprised of a greater number of pixels than the second matrix.

According to a third aspect of the present invention, there is provided a pixel number increasing apparatus comprising an orthogonal transforming processor and an expanded image generating processor.

The orthogonal transforming processor applies orthogonal transformation to image data arranged in a fourth matrix comprised of a plurality of pixels to obtain orthogonal transformation coefficients of image data arranged in the fourth matrix. The expanded image generating processor applies inverse orthogonal transformation to the orthogonal transformation coefficients to obtain expanded image data arranged in a fifth matrix comprised of a greater number of pixels than the fourth matrix.

According to a fourth aspect of the present invention, there is provided a pixel number increasing apparatus comprising an expanded image generating processor that applies inverse orthogonal transformation to image data arranged in a sixth matrix comprised of a plurality of orthogonal

transformation coefficients to obtain expanded image data arranged in a seventh matrix comprised of a greater number of pixels than the sixth matrix.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the description of the preferred embodiments of the invention set forth below, together with the accompanying drawings, in which:

Fig. 1 is a block diagram of an image compression apparatus included in the image compression and expansion apparatus according to a first embodiment of the present invention;

Fig. 2 is a block diagram of an image expansion apparatus included in the image compression and expansion apparatus according to the first embodiment of the present invention;

Fig. 3 is a view of matrixes of image data processed in the image compression and expansion apparatus shown in Fig. 1 and Fig. 2;

Fig. 4 is a view of the reduction processing in a reduced image generator;

Fig. 5 is a view of 8 x 8 pixel values of a second matrix and DCT coefficients corresponding to the image data comprised of the pixel values;

Fig. 6 is a view of the component relating to the DC



component  $F(0)$  in the pixel value and the components relating to the AC components  $F(1)$ ,  $F(2)$ , and  $F(3)$ ;

Fig. 7 is a view of the DCT coefficients of an  $8 \times 8$  matrix and the pixel values comprising a third matrix of reproduced image data;

Fig. 8 is a block diagram of an image compression apparatus included in the image compression and expansion apparatus according to a second embodiment of the present invention; and

Fig. 9 is a block diagram of an image expansion apparatus included in the image compression and expansion apparatus according to the second embodiment of the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described below with reference to embodiments shown in the drawings.

Figs. 1 and 2 are block diagrams of an image compression and expansion apparatus according to a first embodiment of the present invention. Fig. 1 shows an image compression apparatus, while Fig. 2 shows an image expansion apparatus.

Light reflected from a subject being photographed SP is focused by a photographing optical system 11, whereby an optical image of the subject SP is formed on the light receiving surface of an imaging device 12. At the light

receiving surface of the imaging device 12 are provided red (R), green (G), and blue (B) color filters. The imaging device 12 generates analog electrical signals corresponding to the R, G, and B images. These electrical signals are converted to digital electrical signals of the R, G, and B images at an AD converter 13. The R, G, and B image signals are converted to luminance data Y and color difference data Cb, Cr at a not shown image processing circuit and stored in a memory 14.

The luminance data Y and color difference data Cb, Cr are original image data comprised of approximately 1000 pixels in the horizontal direction and approximately 600 pixels in the vertical direction in the image arranged in a matrix. As described later, in a reduced image generator 15, image data is extracted from the original image data for every first matrix comprised of 64 x 64 pixels and the original image data of the first matrix is reduced. In the reduction processing, the original image data is converted to reduced image data comprised by a second matrix. The second matrix is comprised of a smaller number of pixels than the first matrix. That is, the reduced image data is compressed from the luminance data Y and the color difference data Cb, Cr stored in the first memory 14. The compression rate is for example 1/64. The reduced image data is recorded in a recording medium RM such as an IC memory card.

The reduced image data corresponding to the luminance data Y and the color difference data Cb, Cr is read from the recording medium RM and subjected to a two dimensional discrete cosine transformation (DCT) at the DCT processor 21. That is, the reduced image data is converted to DCT coefficients. These DCT coefficients are subjected to the later described expanded two dimensional inverse discrete cosine transformation (expanded IDCT) at an expanded IDCT processor 22. Due to this, expanded image data comprised of a third matrix is obtained and stored in the second memory 23. The expanded image data corresponds to the original image data and is of the format of luminance data Y and color difference data Cb, Cr. Further, the third matrix is comprised of the greater number of pixels than the second matrix. The number of pixels is the same as that of the first matrix.

Fig. 3 is a view of matrixes of image data processed in the image compression and expansion apparatus shown in Fig. 1 and Fig. 2. Fig. 4 is a view of reduction processing in the reduced image generator 15. An explanation will be made next of the operation of the reduced image generator 15 referring to Fig. 3 and Fig. 4.

The original image data is comprised of approximately 1000 x 600 pixel values  $P_{yx}$  and is divided into unit blocks comprised of 8 x 8 pixels. In Fig. 3, the block B1 has the left corner block of the original image data as its origin and

is positioned at the s-th block in the horizontal direction and the t-th block in the vertical direction. The first matrix M1 is comprised by 64 unit blocks comprising 8 blocks in the horizontal direction and 8 in the vertical direction. That is, the first matrix M1 is comprised of 64 x 64 pixel values Pyx.

In the reduced image generator 15, a second matrix M2 is generated for every original image data comprised of a first matrix M1. The pixel value Rts in the second matrix M2 is shown by the following formula (2). That is, the pixel value Rts of the second matrix M2 is obtained by finding the average value of 8 x 8 pixel values Pyx comprising the block B1 in the first matrix M1:

$$Rts = \left( \sum_{x=sx8}^{sx8+7} \sum_{y=tx8}^{tx8+7} Pyx \right) // 64 \dots (2)$$

The origin in the original pixel data is the pixel of the left corner C1 of the image. x shows the coordinate of the pixel in the horizontal direction, while y is the coordinate of the pixel in the vertical direction.

In the example shown in Fig. 4, the block B1 included in the first matrix M1 is comprised of the 64 pixel values Pyx of 160, 158, 183, 211, 221, 226... The average value 174 of the 64 pixel values Pyx is found as the corresponding pixel

value  $R_{ts}$  of the second matrix  $M2$ .

In this way, the second matrix  $M2$  is comprised of  $8 \times 8$  pixel values. The reduced image data comprised of the second matrix  $M2$  shows the original image by fewer pixels than the original image data. In other words, the block  $B1$  positioned at the  $s$ -th block in the horizontal direction of the original image data and the  $t$ -th block in the vertical direction corresponds to the pixel  $P1$  positioned at the  $s$ -th pixel in the horizontal direction of the reduced image data and the  $t$ -th pixel in the vertical direction.

Fig. 5 shows the  $8 \times 8$  pixel values of the second matrix  $M2$  and the DCT coefficients of these pixel values. In the reduced image data read from the recording medium  $RM$ , the pixel value  $R_{ts}$ , which is a component of the second matrix  $M2$ , is shown by an  $(s, t)$  coordinate system having the left corner  $C2$  in the reduced image data as an origin. For the DCT, the pixel value  $R_{ts}$  is converted to a coordinate system having the left corner  $C3$  in the second matrix  $M2$  as an origin in accordance with formula (3):

$$R'_{yx}(s, t) = R_{t+y, s+x} \dots (3)$$

where,  $0 \leq x, y \leq 7$

The DCT is performed in accordance with the following formula (4) at the DCT processor 21:

$$D_{vu}^{(s,t)} = \frac{1}{4} C_u C_v \sum_{x=0}^7 \sum_{y=0}^7 R_{yx}^{(s,t)} \cdot \cos \frac{(2x+1)u\pi}{16} \cos \frac{(2y+1)v\pi}{16} \dots (4)$$

$$\text{where, } C_u, C_v = 1/\sqrt{2} : u, v = 0 \\ C_u, C_v = 1 : u, v \neq 0$$

In the matrix MD comprised of the DCT coefficients  $D_{vu}^{(s,t)}$  obtained by the DCT, the DCT coefficient  $D^{(0,0)}$  at the origin (0,0) is the direct current (DC) component while the remaining 63 DCT coefficients  $D_{vu}^{(s,t)}$  are alternating current (AC) components. The DC component corresponds to the average value of the 8 x 8 pixel values comprising the second matrix, while the AC components correspond to the predetermined spatial frequency components.

The expanded IDCT performed at the expanded IDCT processor 22 is described below.

Here, for simplification of the description, the case where the matrix of the image data is arranged one-dimensionally, that is, one dimensional expanded IDCT, will be explained.

The one dimensional discrete cosine transformation (one dimensional DCT) on the image data comprised of 8 pixels  $P_x$  ( $=P_0, P_1, P_2, \dots, P_7$ ) arranged one-dimensionally is expressed by the following formula (5):

$$F(u) = \frac{1}{2} Cu \sum_{x=0}^7 P_x \cos \frac{(2x+1)u\pi}{16} \dots (5)$$

$$\text{where, } Cu = \frac{1}{\sqrt{2}} : u=0$$

$$Cu=1 : u \neq 0$$

As can be understood from formula (5), a spatial frequency component  $F(u)$  is obtained based on the pixel values  $P_x$  at the 8 regions  $x$  by a one dimensional discrete cosine transformation. The number of types of spatial frequencies (i.e., the number of "u's") is equal to the number of regions  $x$  and is 8 in the case where the number of regions  $x$  is 8. That is, in this case, the DC component  $F(0)$  and the seven AC components  $F(1)$ ,  $F(2)$ , ...  $F(7)$  are obtained.

The one dimensional inverse discrete cosine transformation (one dimensional IDCT) is expressed by the following formula (6):

$$P'_x = \frac{1}{2} \sum_{u=0}^7 Cu F(u) \cos \frac{(2x+1)u\pi}{16} \dots (6)$$

As can be understood from formula (6), a pixel value  $P'_x$  is obtained based on the 8 spatial frequency components  $F(u)$  by the one dimensional inverse discrete cosine transformation.

Fig. 6 shows the component relating to the DC component  $F(0)$  and the components relating to the AC components  $F(1)$ ,  $F(2)$ , and  $F(3)$  in a pixel value  $P'_x$ . The component  $A_0$  of the

pixel value P'x relating to the DC component F(0) is expressed by:

$$\frac{1}{2\sqrt{2}}F(0)$$

The component A1 of the pixel value P'x relating to the AC component F(1) is expressed by:

$$\frac{1}{2}F(1)\cos\frac{(2x+1)\pi}{16}$$

The component A2 of the pixel value P'x relating to the AC component F(2) is expressed by:

$$\frac{1}{2}F(2)\cos\frac{2(2x+1)\pi}{16}$$

The component A3 of the pixel value P'x relating to the AC component F(3) is expressed by:

$$\frac{1}{2}F(3)\cos\frac{3(2x+1)\pi}{16}$$

A pixel value P'x is the sum of the components of the pixel value P'x relating to all of the spatial frequency components F(0), F(1), F(2), ... F(7). For example, the pixel value at x=1 is expressed by the following formula (7):



$$P'_1 = \frac{1}{2} \sum_{u=0}^7 CuF(u) \cos \frac{3u\pi}{16} \dots (7)$$

$$\text{where, } Cu = \frac{1}{\sqrt{2}} : u=0 \\ Cu=1 : u \neq 0$$

In Fig. 6, the components A01, A11, A21, and A31 of the pixel values relating to the spatial frequency components F(0), F(1), F(2), and F(3) in formula (7) are indicated.

Using the same technique as when obtaining the pixel value P'i at x=1, that is, by interpolation at the curves of the components A0, A1, A2, A3... (see Fig. 6) of the pixel value P'x relating to the spatial frequency components F(0), F(1), ... F(7), it is possible to obtain the pixel values P'x at any region x. For example, the pixel values, when dividing the range 0 to 7 of the region x of the pixels equally by 64, that is, relating to x = 0, 0.125, 0.25, 0.375, 0.5, 0.625, ... 6.875, and 7.0, are obtained by formula (8):

$$P'_x = \frac{1}{2} \sum_{u=0}^7 CuF(u) \cos \frac{(2x+1)u\pi}{128} \dots (8)$$

Note that in formula (8), the denominator of the cosine was made 128 so as to handle the regions x as integer numbers.

Further finely dividing the range of the regions x and performing inverse discrete cosine transformation in this way is called "expanded IDCT" in this specification. The expanded IDCT can also be applied to two dimensional array image data

in the same way as the case of such one dimensional array image data. Formula (9) shows a formula for performing the expanded IDCT in the case of a two dimensional array and obtaining the image values  $I'^{(s,t)}_{yx}$ .

$$I'^{(s,t)}_{yx} = \frac{1}{4} \sum_{u=0}^7 \sum_{v=0}^7 C_u C_v D^{(s,t)}_{vu} \cdot \cos \frac{(2x+1)u\pi}{128} \cos \frac{(2y+1)v\pi}{128} \dots (9)$$

where,  $0 \leq x \leq 63, 0 \leq y \leq 63$

According to the expanded IDCT shown in formula (9), the 8 x 8 DCT coefficients  $D^{(s,t)}_{vu}$  comprising the matrix MD, as shown in Fig. 7, are transformed into a third matrix M3 comprised of 64 x 64 pixel values  $I'^{(s,t)}_{yx}$ . The third matrix M3 forms the expanded image data as described above.

The coordinates (x,y) of a pixel value  $I'^{(s,t)}_{yx}$  in the third matrix M3 are based on the pixel of the left corner as the origin in the same way as the second matrix M2. Therefore, to return a pixel value  $I'^{(s,t)}_{yx}$  of the third matrix M3 to the same coordinate system as the original image data, coordinate transformation is performed in accordance with formula (10) and the coordinate transformed enlarged image data is stored in the second memory 23 (see Fig. 1).

$$J_{tx8+y, sx8+y} = I'^{(s,t)}_{yx} \dots (10)$$

As can be understood from formula (10), the coordinates

of a pixel value  $I'^{(s,t)}_{yx}$  in the expanded image data are obtained from the position  $(s,t)$  of the block B1 (see Fig. 3) corresponding to the third matrix M3 and the position  $(s$ -th block,  $t$ -th block) of the pixel value  $I'^{(s,t)}_{yx}$  in the third matrix M3.

As explained above, according to the present embodiment, by applying DCT and expanded IDCT to the reduced image data, it is possible to obtain expanded image data (expanded image) of the same size and the same number of pixels as the original image data. In the expanded IDCT, as shown by formula (9), the pixel values of the expanded image data are obtained by applying the two dimensional inverse discrete cosine transformation directly to the result obtained by the DCT to generate each of the elements forming the third matrix M3. Therefore, according to the present embodiment, despite the loss of information at the time of generating reduced image data, it becomes possible to reproduce an image close to the original image and improve the quality of the reproduced expanded image.

Note that the number of pixels forming the second and third matrixes M2 and M3 can be freely set. That is, when making  $n_1$ ,  $m_1$ ,  $n_2$ ,  $m_2$ ,  $N$ , and  $M$  positive integers, the second matrix is comprised of  $n_1 \times m_1$  pixels and the third matrix is comprised of  $n_2 \times m_2$  pixels. Here,  $n_2$  is  $2^N$  times  $n_1$  and  $m_2$  is  $2^M$  times  $m_1$ .

In this embodiment, the number of pixels is reduced from the original image data to generate reduced image data, then the number of pixels is increased by the expanded IDCT to generate enlarged image data, but the reduced image data can be deemed original image data. That is, first, the two dimensional discrete cosine transformation is applied to the original image data comprised of the fourth matrix (corresponding to the second matrix M2) comprised of, for example, 8 x 8 pixels so as to obtain the DCT coefficients of the original image data. Further, the expanded IDCT is applied to the DCT coefficients to obtain expanded image data comprised of a fifth matrix (corresponding to the third matrix M3) comprised of, for example, 64 x 64 pixels. By this configuration, it becomes possible to increase the number of pixels of original image data comprised by the fourth matrix to improve the quality of the reproduced image.

Fig. 8 and Fig. 9 are block diagrams showing an image compression and expansion apparatus according to a second embodiment. Fig. 8 shows an image compression apparatus, while Fig. 9 shows an image expansion apparatus. The same reference numerals are used for components the same as or equivalent to the first embodiment shown in Fig. 1 and Fig. 2.

Components different from those of the first embodiment will be described. The reduced image data comprised of the

second matrix M2 (see Fig. 3) comprised of 8 x 8 pixels generated in the reduced image generator 15 is subject to the two dimensional discrete cosine transformation at the DCT processor 16. The number of elements of the matrix MD (see Fig. 3) obtained by this, that is, the number of DCT coefficients, is 8 x 8. This is less than the first matrix M1 (see Fig. 3) forming the original image data. The matrix MD forms the reduced DCT coefficient data. The reduced DCT coefficient data is recorded on the recording medium RM.

The reduced DCT coefficient data is read from the recording medium RM and the expanded two dimensional inverse discrete cosine transformation is applied at the expanded IDCT processor 22. Due to this, enlarged image data comprised of a third matrix M3 (see Fig. 3) is obtained. That is, in the second embodiment, since reduced DCT coefficient data comprised of DCT coefficients is recorded on the recording medium RM, no DCT processor is provided before the enlarged IDCT processor 22.

The rest of the configuration and mode of operation are the same as those of the first embodiment.

Note that in the second embodiment as well, it is possible to view the reduced DCT coefficient data as the original image data and apply expanded IDCT to it so as to increase the number of pixels. That is, first, expanded IDCT is applied to the DCT coefficients of original image comprised

of a sixth matrix (corresponding to matrix MD) comprised of, for example, 8 x 8 DCT coefficients to obtain enlarged image data comprised of a seventh matrix (corresponding to third matrix M3) comprised of, for example, 64 x 64 pixels. In this configuration as well, it is possible to increase the number of pixels of original image data comprised of the sixth matrix and improve the quality of the reproduced image.

In the above embodiments, the two dimensional discrete cosine transformation was used for the orthogonal transformation and the two dimensional inverse discrete cosine transformation was used for the inverse orthogonal transformation, but the invention is not limited to this. It is also possible to use another known orthogonal transformation and inverse orthogonal transformation.

As described above, according to the present invention, it becomes possible to provide an image compression and expansion apparatus for generating an enlarged image corresponding to an original image from a reduced image, which can improve the quality of the enlarged image.

While the invention has been described with reference to specific embodiment chosen for purpose of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

Although the embodiments of the present invention have

been described herein with reference to the accompanying drawings, obviously many modifications and changes may be made by those skilled in this art without departing from the scope of the invention.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 11-14143 (filed on January 22, 1999) which is expressly incorporated herein, by reference, in its entirety.

## CLAIMS

1. An image compression and expansion apparatus comprising:

a reduced image generating processor that generates, based on original image data arranged in a first matrix comprised of a plurality of pixels, reduced image data arranged in a second matrix comprised of a smaller number of pixels than said first matrix;

a reduced image recording processor that records said reduced image data in a recording medium;

an orthogonal transforming processor that reads said reduced image data from said recording medium and applies orthogonal transformation to obtain orthogonal transformation coefficients arranged in said second matrix; and

an expanded image generating processor that applies inverse orthogonal transformation to said orthogonal transformation coefficients to obtain expanded image data arranged in a third matrix comprised of a greater number of pixels than said second matrix.

2. An image compression and expansion apparatus comprising:

a reduced image generating processor that generates, based on original image data arranged in a first matrix comprised of a plurality of pixels, reduced image data arranged in a second matrix comprised of a smaller number of



pixels than said first matrix;

a reduced orthogonal transformation coefficient data recording processor that records reduced orthogonal transformation coefficient data, obtained by orthogonal transformation of said reduced image data, in a recording medium; and

an expanded image generating processor that reads said reduced orthogonal transformation coefficient data from said recording medium and applies inverse orthogonal transformation to obtain expanded image data arranged in a third matrix comprised of a greater number of pixels than said second matrix.

3. The image compression and expansion apparatus according to one of claims 1 and 2, wherein said reduced image generating processor obtains an average value of a predetermined number of pixel values included in said first matrix, and sets said average value as one pixel value corresponding to a predetermined number of pixels included in said second matrix.

4. The image compression and expansion apparatus according to claim 3, wherein said average value is obtained from 8 x 8 pixel values included in said first matrix.

5. The image compression and expansion apparatus according to one of claims 1 and 2, wherein said second and third matrixes are comprised of  $n_1 \times m_1$  and  $n_2 \times m_2$  pixels,

respectively, and  $n_2$  and  $m_2$  are  $2^N$  times  $n_1$  and  $2^M$  times  $m_1$ , respectively (where  $n_1$ ,  $m_1$ ,  $n_2$ ,  $m_2$ ,  $N$  and  $M$  are positive integers).

6. The image compression and expansion apparatus according to one of claims 1 and 2, wherein said first matrix is comprised of  $64 \times 64$  pixels and said second matrix is comprised of  $8 \times 8$  pixels.

7. The image compression and expansion apparatus according to one of claims 1 and 2, wherein the numbers of pixels contained in said first and third matrixes are the same.

8. The image compression and expansion apparatus according to one of claims 1 and 2, wherein said first and third matrixes are each comprised of  $64 \times 64$  pixels.

9. The image compression and expansion apparatus according to one of claims 1 and 2, wherein said orthogonal transformation is a two dimensional discrete cosine transformation and said inverse orthogonal transformation is a two dimensional inverse discrete cosine transformation.

10. The image compression and expansion apparatus according to claim 9, wherein said first, second, and third matrixes are comprised of  $64 \times 64$ ,  $8 \times 8$ , and  $64 \times 64$  pixels, respectively, and said expanded image generating processor obtains expanded image data by a two dimensional inverse discrete cosine transformation expressed by the following formula:

$$I'_{yx}(s, t) = \frac{1}{4} \sum_{u=0}^7 \sum_{v=0}^7 C_u C_v D_{vu}^{(s, t)} \cdot \cos \frac{(2x+1)u\pi}{128} \cos \frac{(2y+1)v\pi}{128}$$

wherein,  $0 \leq x \leq 63$ ,  $0 \leq y \leq 63$ ,  $I'_{yx}$  is the pixel value of expanded image data,  $C_u, C_v = 1/2^{1/2}$  when  $u, v = 0$ ,  $C_u, C_v = 1$  when  $u, v \neq 0$ , and  $D_{vu}$  is a DCT coefficient obtained by said two dimensional discrete cosine transformation.

11. A pixel number increasing apparatus comprising:

an orthogonal transforming processor that applies orthogonal transformation to image data arranged in a fourth matrix comprised of a plurality of pixels to obtain orthogonal transformation coefficients of image data arranged in said fourth matrix; and

an expanded image generating processor that applies inverse orthogonal transformation to said orthogonal transformation coefficients to obtain expanded image data arranged in a fifth matrix comprised of a greater number of pixels than said fourth matrix.

12. The pixel number increasing apparatus according to claim 11, wherein said orthogonal transformation is a two dimensional discrete cosine transformation and said inverse orthogonal transformation is a two dimensional inverse discrete cosine transformation.

13. The pixel number increasing apparatus according to claim 12, wherein said fourth and fifth matrixes are comprised

of 8 x 8 and 64 x 64 pixels, respectively, and said expanded image generating processor obtains expanded image data by said two dimensional inverse discrete cosine transformation expressed by the following formula:

$$I'_{yx}(s, t) = \frac{1}{4} \sum_{u=0}^7 \sum_{v=0}^7 C_u C_v D_{vu}^{(s, t)} \cdot \cos \frac{(2x+1)u\pi}{128} \cos \frac{(2y+1)v\pi}{128}$$

wherein,  $0 \leq x \leq 63$ ,  $0 \leq y \leq 63$ ,  $I'_{yx}$  is the pixel value of expanded image data,  $C_u, C_v = 1/2^{1/2}$  when  $u, v=0$ ,  $C_u, C_v=1$  when  $u, v \neq 0$ , and  $D_{vu}$  is a DCT coefficient obtained by said two dimensional discrete cosine transformation.

14. A pixel number increasing apparatus comprising an expanded image generating processor that applies inverse orthogonal transformation to image data arranged in a sixth matrix comprised of a plurality of orthogonal transformation coefficients to obtain expanded image data arranged in a seventh matrix comprised of a greater number of pixels than said sixth matrix.

15. The pixel number increasing apparatus according to claim 14, wherein said orthogonal transformation is a two dimensional discrete cosine transformation and said inverse orthogonal transformation is a two dimensional inverse discrete cosine transformation.

16. The pixel number increasing apparatus according to claim 15, wherein said sixth and seventh matrixes are

comprised of 8 x 8 and 64 x 64 pixels, respectively, and said expanded image generating processor obtains expanded image data by said two dimensional inverse discrete cosine transformation expressed by the following formula:

$$I'_{yx}(s, t) = \frac{1}{4} \sum_{u=0}^7 \sum_{v=0}^7 C_u C_v D_{vu}(s, t) \cdot \cos \frac{(2x+1)u\pi}{128} \cos \frac{(2y+1)v\pi}{128}$$

wherein,  $0 \leq x \leq 63$ ,  $0 \leq y \leq 63$ ,  $I'_{yx}$  is the pixel value of expanded image data,  $C_u, C_v = 1/2^{1/2}$  when  $u, v=0$ ,  $C_u, C_v=1$  when  $u, v \neq 0$ , and  $D_{vu}$  is a DCT coefficient obtained by said two dimensional discrete cosine transformation.

IMAGE COMPRESSION AND EXPANSION APPARATUS AND PIXEL NUMBER  
INCREASING APPARATUS

ABSTRACT OF THE DISCLOSURE

An image compression and expansion apparatus reproduces an expanded image corresponding to an original image from a reduced image. The original image data is comprised of approximately 1000 x 600 pixel values  $P_{yx}$ . A first matrix  $M_1$  comprised of 64 x 64 pixel values  $P_{yx}$  is extracted from the original image data. Regarding the original image data arranged in the first matrix  $M_1$ , an average value of 8 x 8 pixel values  $P_{yx}$  forming a block  $B_1$  is obtained, and thus a second matrix  $M_2$  is generated using the average value as a single pixel value. The pixel values of the second matrix  $M_2$  is subject to two dimensional discrete cosine transformation to obtain a matrix  $M_D$  comprised of 8 x 8 DCT coefficients. Expanded two dimensional inverse discrete cosine transformation is applied to the matrix  $M_D$  to obtain a third matrix  $M_3$  comprised of 64 x 64 pixel values. The expanded image data comprising the third matrix  $M_3$  is transformed to the same coordinate system as the original image data and recorded on to the recording medium.

FIG. 1

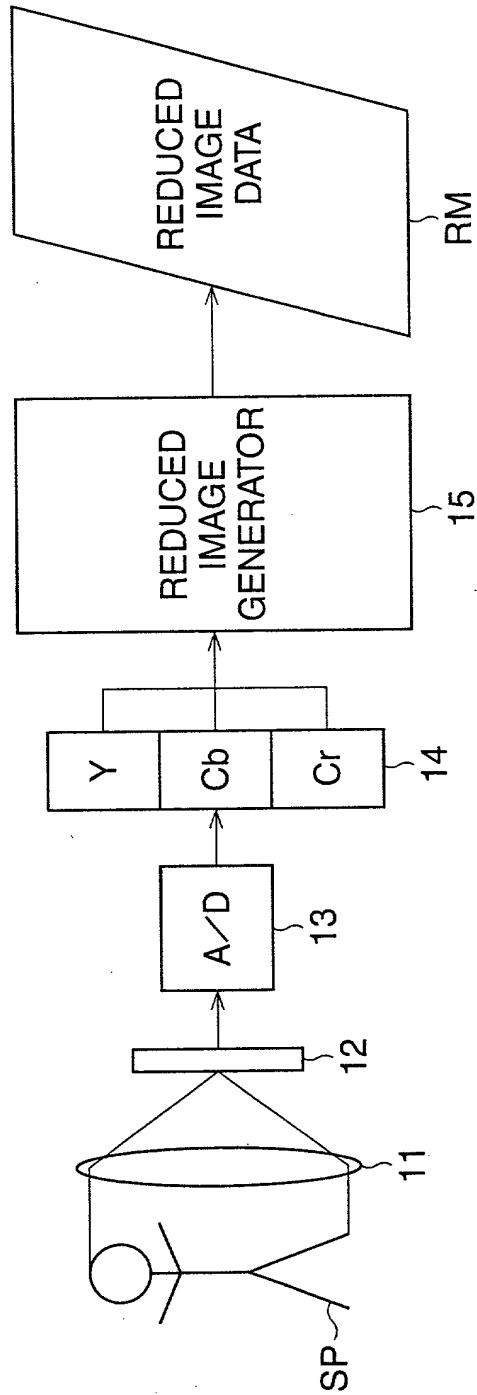


FIG. 2

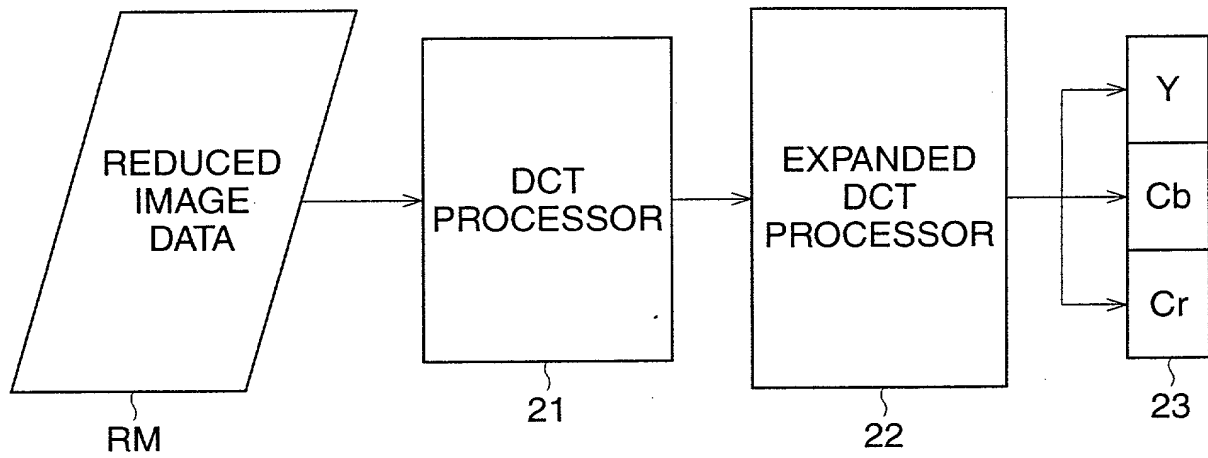




FIG. 3

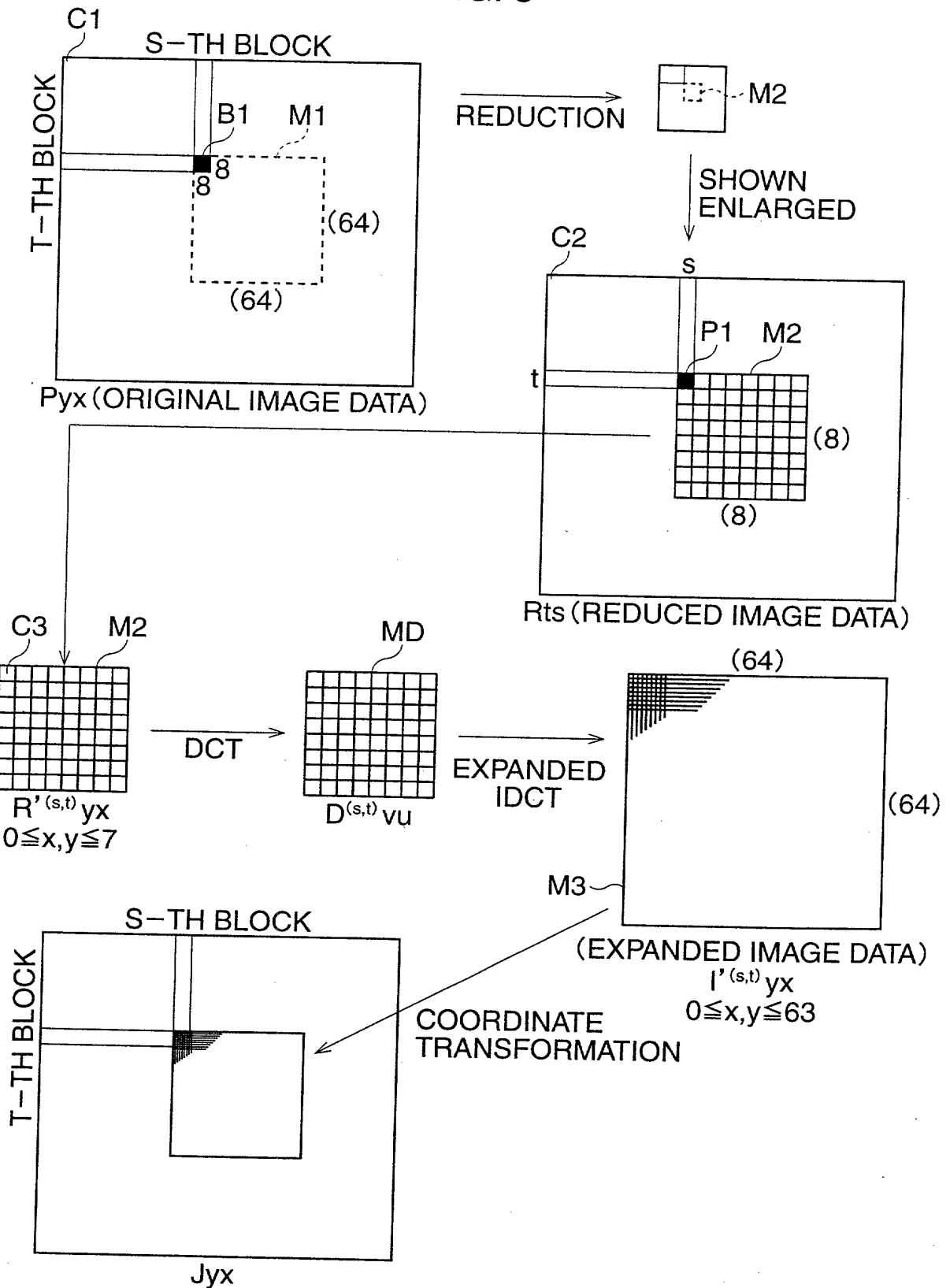


FIG. 4

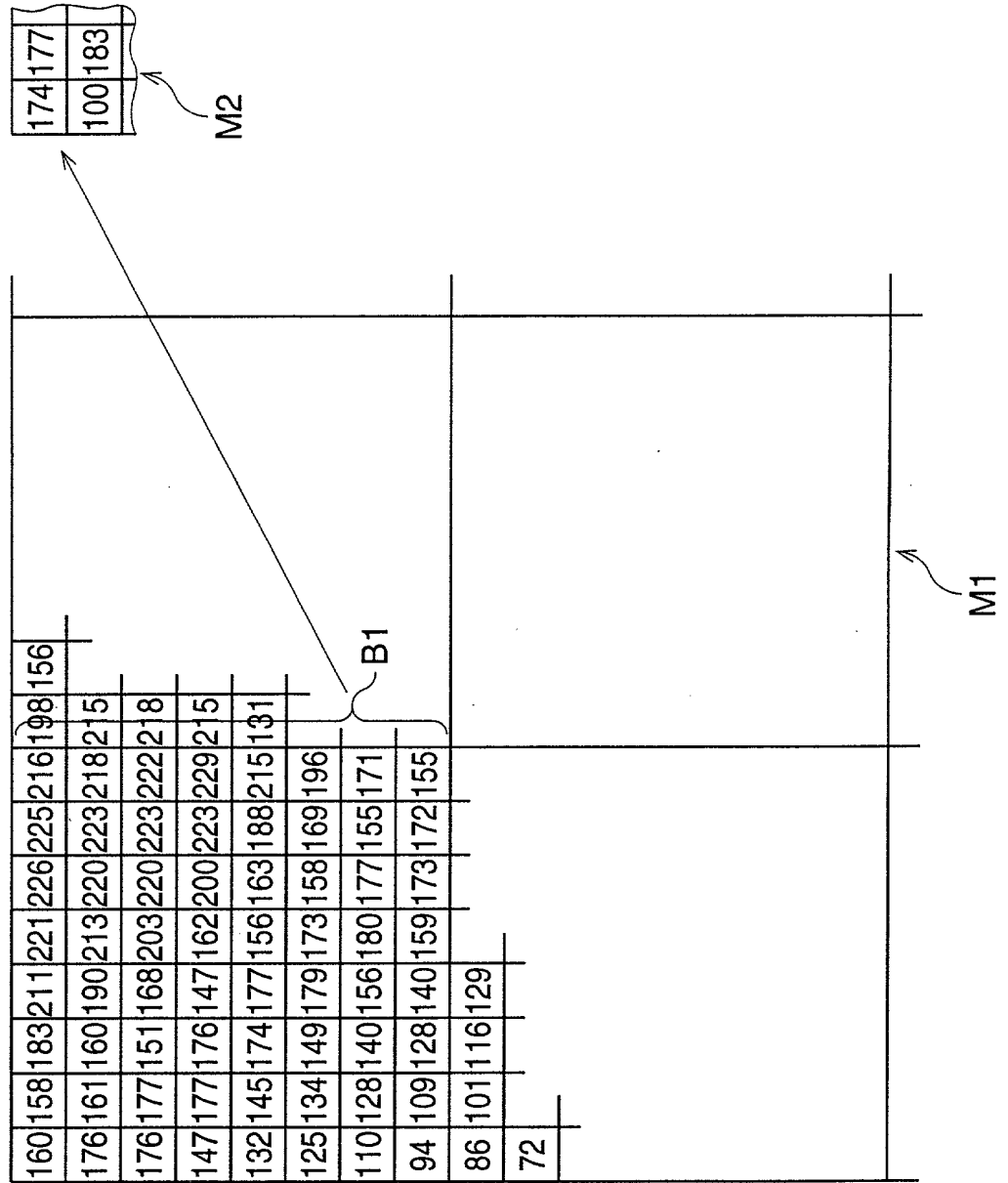


FIG. 5

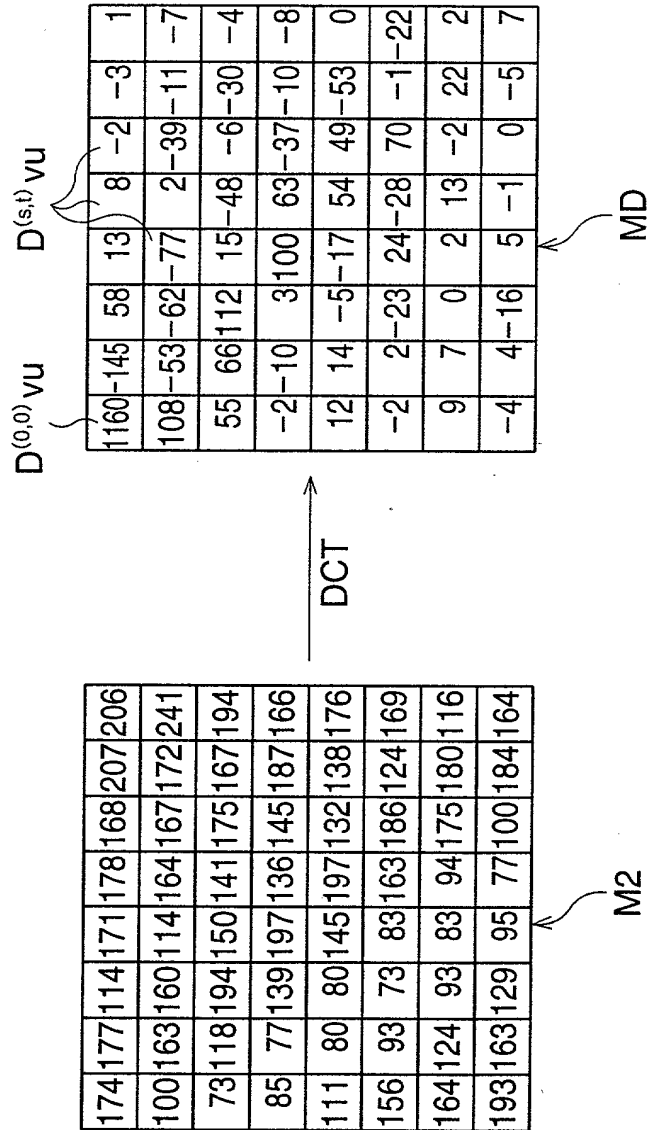


FIG. 6

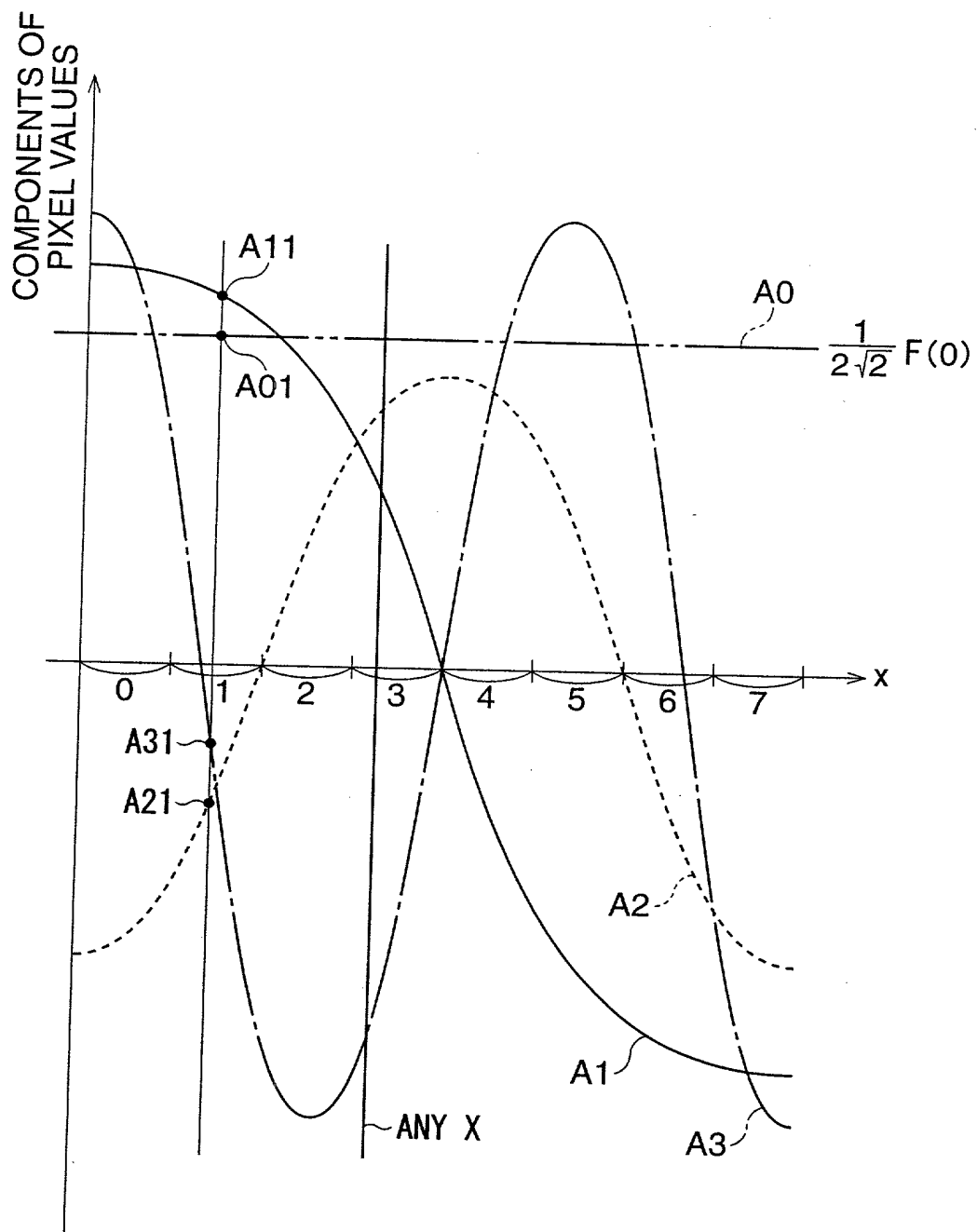




FIG. 8

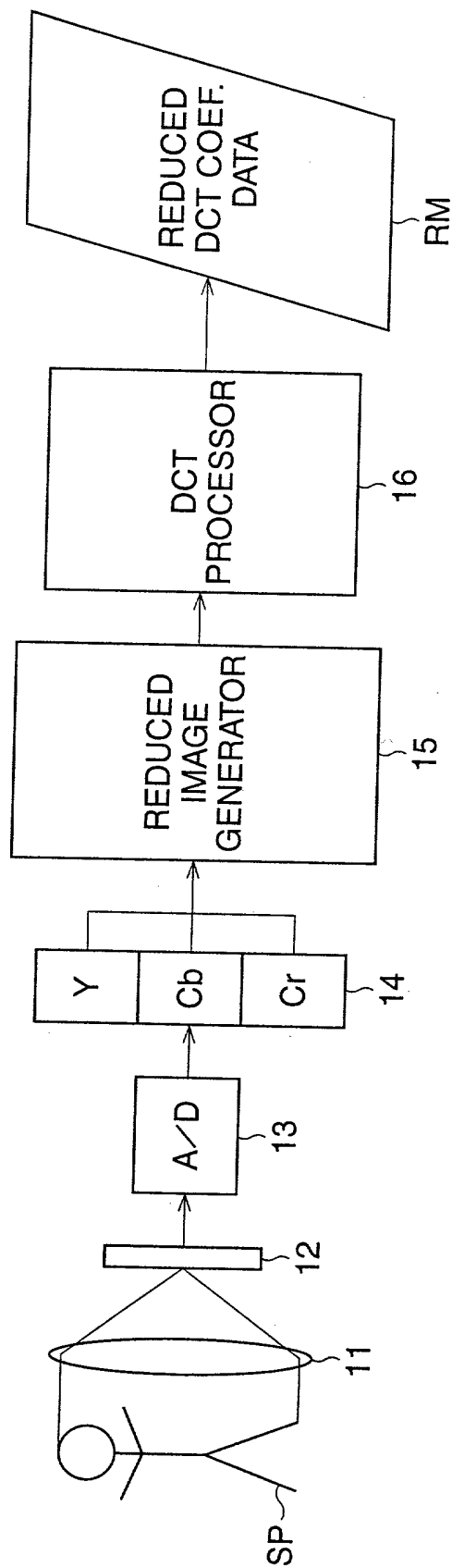
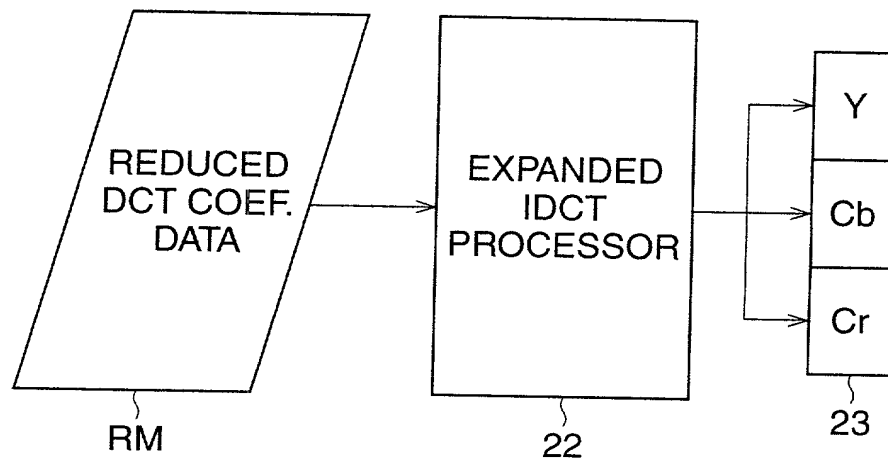


FIG. 9



# Declaration and Power of Attorney For Utility or Design Patent Application

## 特許出願宣言書

### Japanese Language Declaration

私は、下欄に氏名を記載した発明者として、以下のとおり  
宣言する：

私の住所、郵便の宛先および国籍は、下欄に氏名に続いて記載したとおり  
であり、

名称の発明に関し、請求の範囲に記載した特許を求める主題の本来の、  
最初にして唯一の発明者である(一人の氏名のみが下欄に記載されている  
場合)か、もしくは本来の、最初にして共同の発明者である(複数の氏名が  
下欄に記載されている場合)と信じ、

その明細書を

(該当するほうに印を付す)

☐ここに添付する。

☐ \_\_\_\_\_ 日に 出願番号

第 \_\_\_\_\_ 号として提出し、

\_\_\_\_\_ 日に補正した。

(該当する場合)

私は、前記のとおり補正した請求の範囲を含む前記明細書の内容を検討  
し理解したことを陳述する。

私は、連邦規則法典第37部第1章第56条に従い、本題の審査に所要の  
情報を開示すべき義務を有することを認める。

私は合衆国法典第35部第119条(a-d)項又は第365条(b)項に基づく、下  
記の外国特許出願又は発明者証出願、或いは第365条(a)項に基づく、少な  
くとも米国以外の1ヶ国を指名したPCT国際出願の外国優先権利益を主張  
し、更に優先権の主張に係わる基礎出願の出願日前の出願日を有する外国  
特許出願、又は発明者証出願或いはPCT国際出願を以下に明記する：

Prior foreign applications  
先の外国出願

P11-014143	Japan	22/January/1999
(Number)	(Country)	(Day/Month/Year Filed)
(番号)	(国名)	(出願の年月日)
_____	_____	_____
(Number)	(Country)	(Day/Month/Year Filed)
(番号)	(国名)	(出願の年月日)
_____	_____	_____
(Number)	(Country)	(Day/Month/Year Filed)
(番号)	(国名)	(出願の年月日)
_____	_____	_____

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated  
below next to my name.

I believe I am the original, first and sole inventor (if only one name is  
listed below) or an original, first and joint inventor (if plural names  
are listed below) of the subject matter which is claimed and for  
which a patent is sought on the invention entitled

IMAGE COMPRESSION AND EXPANSION APPARATUS

AND PIXEL NUMBER INCREASING APPARATUS

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on \_\_\_\_\_ as

Application No. \_\_\_\_\_

and was amended on \_\_\_\_\_

(if applicable)

I hereby state that I have reviewed and understand the contents of  
the above identified specification, including the claims, as amended  
by any amendment referred to above.

I acknowledge the duty to disclose information which is material to  
the examination of this application in accordance with Title 37, Code  
of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States  
Code §119(a-d) or §365(b) of any foreign application(s) for patent  
or inventor's certificate, or §365(a) of any PCT international  
application which designated at least one country other than the  
United States of America, listed below and have also identified  
below, by checking the "No" box, any foreign application for patent  
or inventor's certificate, or of any PCT international application having  
a filing date before that of the application on which priority is claimed:

Priority claimed  
優先権の主張

<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
あり	なし
<input type="checkbox"/> Yes	<input type="checkbox"/> No
あり	なし
<input type="checkbox"/> Yes	<input type="checkbox"/> No
あり	なし



## Japanese Language Utility or Design Patent Application Declaration

☐ その他の外国特許出願番号は別紙の追補優先権欄にて記載する。

☐ Additional foreign application numbers are listed on a supplemental priority sheet attached hereto.

私は、合衆国法典第35部第119条(e)項に基づく、下記の合衆国仮特許出願の利益を主張する。

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below.

(Number) (番号)	(Day/Month/Year Filed) 出願の年月日
(Number) (番号)	(Day/Month/Year Filed) 出願の年月日
(Number) (番号)	(Day/Month/Year Filed) 出願の年月日

☐ その他の合衆国仮特許出願番号は別紙の追補優先権欄にて記載する。

☐ Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.

私は、合衆国法典第35部第120条に基づく下記の合衆国特許出願、又は第365条(c)項に基づく合衆国を指名したPCT国際出願の利益を主張し、本願の請求の範囲各項に記載の主題が合衆国法典第35部第112条第1項規定の態様で、先の合衆国特許出願又はPCT国際出願に開示されていない限度において、先の出願の出願日と本願の国内出願日又はPCT国際出願日の間に有効となった連邦規則法典第37部第1章第56条に記載の特許要件に所要の情報を開示すべき義務を有することを認める。

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s), or §365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application No.) (出願番号)	(Day/Month/Year Filed) (出願の年月日)
(Application No.) (出願番号)	(Day/Month/Year Filed) (出願の年月日)

(現況) (特許済み、係属中 放棄済み)	(Status) (patented, pending, abandoned)
(現況) (特許済み、係属中 放棄済み)	(Status) (patented, pending, abandoned)

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☐ Additional U.S. or international application numbers are listed on a supplemental priority sheet attached hereto.

私は、ここに自己の知識にもとずいて行った陳述がすべて真実であり、自己の有する情報および信ずるところに従って行った陳述が真実であると信じ、さらに故意に虚偽の陳述等を行った場合、合衆国法典第18部第1001条により、罰金もしくは禁錮に処せられるか、またはこれらの刑が併科され、またかかる故意による虚偽による陳述が本願ないし本願に対して付与される特許の有効性を損なうことがあることを認識して、以上の陳述を行ったことを宣言する。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

私、下記署名者は、ここに記載の米国弁護士または代理人に本出願に関し特許商標庁にて取られるいかなる行為に関して、同米国弁護士又は代理人が、私に直接連絡なしに私の外国弁護士或いは法人代表者からの指示を受け取り、それに従うようここに委任する。この指示を出す者が変更の場合には、ここに記載の米国弁護士又は代理人にその旨通知される。

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from either his foreign patent agent or corporate representative, if any, as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

# Japanese Language Utility or Design Patent Application Declaration

委任状： 私は、下記発明者として、下記に明記された顧客番号を伴う以下の弁護士又は、代理人をここに選任し、本順の手続きを遂行すること並びにこれに関する一切の行為を特許商標庁に対して行うことを委任する。そして全ての通信はこの顧客番号宛に発送される。

顧客番号 7055

現在選任された弁護士は下記の通りである。

Neil F. Greenblum  
Bruce H. Bernstein  
Roger P. Glass  
James L. Rowland  
Arnold Turk

Reg. No. 28,394  
Reg. No. 29,027  
Reg. No. 30,841  
Reg. No. 32,674  
Reg. No. 33,094

Address: **GREENBLUM & BERNSTEIN, P.L.C.**  
1941 ROLAND CLARKE PLACE  
RESTON, VA 20191

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorney(s) and/or agent(s) associated with the Customer Number provided below to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to that Customer Number:

**CUSTOMER NUMBER 7055**

The appointed attorneys presently include:

直接電話連絡先：(名称および電話番号)

Direct Telephone Calls to: (name and telephone number)

**GREENBLUM & BERNSTEIN, P.L.C.**  
(703) 716-1191

唯一のまたは第一の発明者の氏名	Full name of sole or first inventor
	Nobuaki ABE
同発明者の署名	Inventor's signature
日付	Date
	Nobuaki Abe January 17, 2000
住所	Residence
	Hokkaido, Japan
国籍	Citizenship
	Japan
郵便の宛先	Post Office Address
	c/o Pentax Technology Sapporo of Asahi Kogaku Kogyo K.K., 1-1-10, Shimonoppo Techno Park, Atsubetsu-ku, Sapporo, Hokkaido, Japan
第2の共同発明者の氏名 (該当する場合)	Full name of second joint inventor, if any
同第2共同発明者の署名	Second Inventor's signature
日付	Date
住所	Residence
国籍	Citizenship
郵便の宛先	Post Office Address

(第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。)

(Supply similar information and signature for third and subsequent joint inventors.)